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A PROLONGED SAPROPHYTIC STAGE OF THE COTTON ROOT-ROT FUNGUS

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INTRODUCTION

The plant disease known as Texas cotton root rot is very generally considered to be caused by a soil-inhabiting fungus, *Phymatotrichum omnivorum* (Shear) Duggar.[1] Most if not all of the taprooted plants are susceptible to attack by this fungus. It apparently does not attack nor exist upon grasses. By the majority of investigators it is agreed that the causal organism may exist in the soil under certain conditions either as a saprophyte or as a parasite. Shear[2] in his original description of the species states:

> This fungus is a facultative parasite infesting the soil and attacking the roots of a great variety of plants and causing serious damage to cultivated crops, such as cotton, alfalfa, cowpeas, sweet potatoes, beets, and fruit trees. Few crops except grasses and grains are free from it.

Peltier, King, and Samson[3] state that "it is not absolutely essential that the roots remain alive, for many observations have been made of dead cotton roots covered with Ozonium mycelium which were not only the source of conidial mats but also producing centers of infection." Taubenhaus and Killough,[4] however, assert that the organism needs a living host to enable it to maintain itself in the soil.

There has been some uncertainty as to how long this fungus could survive in the soil in the absence of living host plants. On the assumption that this period might not be long, recommendations have been made for the control of the disease by periods of clean fallow or rotations including nonsusceptible crops. Experiments conducted at San Antonio, Tex., since 1912 have shown that, although

[1] Originally described by Shear as *Ozonium omnivorum* and later, upon discovery of its conidial stage, described by Duggar as *Phymatotrichum omnivorum*. DUGGAR, B. M. THE TEXAS ROOT ROT FUNGUS AND ITS CONIDIAL STAGE. Ann. Missouri Bot. Gard. 3: 11–23, illus. 1916.

[2] SHEAR, C. L. NEW SPECIES OF FUNGI. Bul. Torrey Bot. Club 34: 305. 1907.

[3] PELTIER, G. L., KING, C. J., and SAMSON, R. W. OZONIUM ROOT ROT. U. S. Dept. Agr. Bul. 1417, 28 p., illus. 1926.

[4] TAUBENHAUS, J. J., and KILLOUGH, D. T. TEXAS ROOT ROT OF COTTON AND METHODS OF ITS CONTROL. Tex. Agr. Expt. Sta. Bul. 307, 98 p., illus. 1923.

the degree of infection may be somewhat reduced, these methods do not eliminate the trouble nor give satisfactory reduction of infection. At Greenville, Tex., on the other hand, clean fallowing of the land for two years has shown definitely beneficial results. In fields held fallow or used for crops generally considered immune from cotton root rot for one or more years prior to cropping to cotton or alfalfa, it has been observed at San Antonio that diseased areas would appear, well isolated from any possible source of infection around the borders of the field. Observations made during the season of 1927 at the United States San Antonio Field Station seem to offer a plausible explanation for this recurrence of the disease.

OBSERVATIONS AT SAN ANTONIO, TEX.

There is on the United States San Antonio Field Station, in the east end of what is known as field E–3, a small tract of land that was cleared of native mesquite growth some time prior to January, 1906. During the years 1906, 1907, and 1908 this land was not cropped; in 1909 it was cultivated and held in a condition of clean fallow, and in 1910 it was planted to a pecan orchard. The pecan trees were gradually killed out by cotton root rot. As there were only a very few of these trees alive in 1922, this area was seeded to alfalfa in November of that year. Seven months after being planted the alfalfa began dying of root rot in scattered spots. The stand had become so poor by 1925 that it was plowed up in August of that year. Weed growth was held in check by frequent cultivation until November, 1926, when the field was seeded to wheat. A shallow drain that borders this field often overflows in times of heavy showers or rains, inundating the eastern portion and causing it to produce unusually rank growth. The soil is Houston clay loam and extends to a depth of at least 4 feet. The wheat crop was harvested May 4, 1927, leaving a very heavy lodged stubble.

The month of May, 1927, was unusually dry and hot, and no weed or grass growth occurred from the time the wheat was harvested until after the rains started in June. From June 4 to June 21, inclusive, cloudy weather with frequent rains prevailed, the total precipitation for the period being 7.24 inches.

On June 22 a characteristic cotton root-rot spore mat, which had apparently been produced during the preceding four to six days, was found growing under lodged wheat stubble. The only taprooted plants in the vicinity of the mat consisted of a field of seedling cotton 20 feet to the north, planted April 15, and a pecan tree of the orchard planted in 1910, which was 40 feet to the southeast. Because of its distance from any visible living host it was decided to watch this formation for further development and, when the soil should become workable, to excavate the location for the purpose of discovering, if possible, from what source it was being produced. While some showery weather occurred later in June, only a very small amount of additional growth occurred, and when dry weather set in the mat became brown and disintegrated.

On July 7 the excavation of the mat was begun. The lodged wheat stubble was first cleared away to permit an examination of the aboveground vegetation within a radius of 4 or 5 feet. The only live growth found consisted of seedling grasses. A semicircular

trench, approximately 16 inches wide and having a radius of 30 inches with the spore mat as a center, was then excavated to a depth of 46 inches. (Fig. 1.) Each shovelful of soil was crumbled with the fingers and examined carefully to discover any bits of either dead or live plant material or fungus mycelium. After the trench was completed, the core of earth left standing directly below the spore mat was likewise excavated, crumbled, and examined.

In digging the trench a snag of a tree root was found with its upper end just below plow depth (10 inches from the surface). This root was so thoroughly rotted on the outside that none of the bark or sapwood could be found, only the heartwood remaining. Many large strands of typical root-rot mycelium were plainly visible over the surface of this decayed root. (Fig. 2.) As the excavation proceeded,

FIGURE 1.—Excavation made for the purpose of determining the origin of a root-rot spore mat in field E-3, U. S. San Antonio Field Station, San Antonio, Tex.

many small dead tree roots were found, mostly varying in diameter from one-eighth to three-eighths of an inch. The deepest root excavated was at a measured depth of 42 inches. Every small piece of the dead tree root found, without a single exception, bore root-rot mycelium. Excavation of the column of earth showed that the soil directly below the spore mat was literally held together by the cinnamon-brown mycelial strands. These strands, in contact with no roots of any kind, could be traced to a depth of 4 to 6 inches through the soil. As in excavating the trench, no live roots of any nature were found under the spore mat except a few seedling grass roots near the surface.

Small portions of grass and tree roots found at various levels were placed in containers, having false bottoms of wet blotting paper, that had been taken to the field for the purpose of collecting specimens

for microscopic examination. Within 24 hours new growth from the strands of mycelium could be detected, mostly at the broken ends of the dead roots. Under the microscope this new growth was found to contain an abundance of the characteristic acicular, right-angle branched hyphæ. Although they were subjected to close examination, no characteristic root-rot mycelium was found on any of the grass roots.

Two additional spore mats of *Phymatotrichum omnivorum*, formed during the wet weather of June, were later found in another portion of this same field. These two locations were excavated. Directly beneath one mat an old, thoroughly rotted mesquite stump was found, and in the subsoil beneath the other there were several rotted

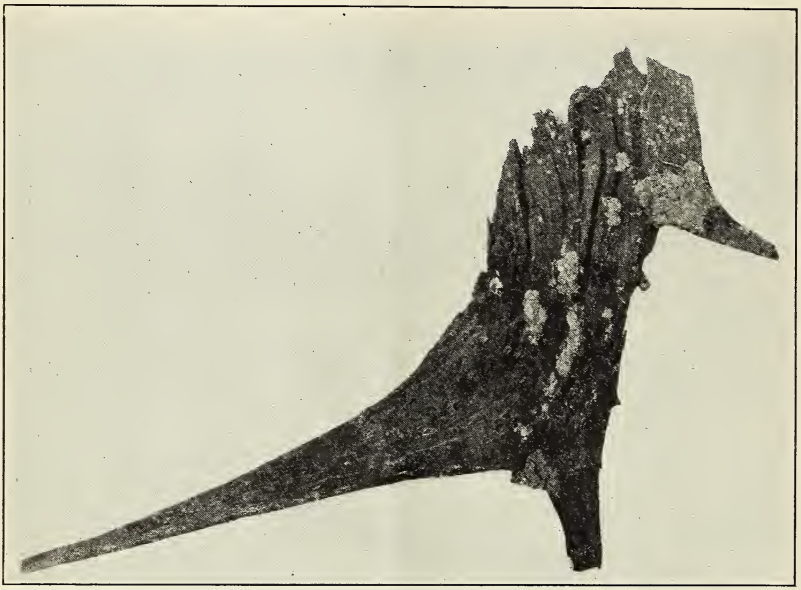

FIGURE 2.—Thoroughly rotted tree stump found under root-rot spore mat. Characteristic mycelium of the root-rot fungus is plainly visible on its surface. U. S. San Antonio Field Station

roots of a Ligustrum tree that had been removed from the field in 1922.

An isolated area of infection occurred in one of a pair of ¼-acre plots at the field station on which cotton is grown every alternate year, clean fallow being maintained during the other years. Each plot is 41.25 feet wide by 264 feet long, an alley 4.75 feet in width separating the plots. Because of a complete failure to secure a stand of cotton in 1923, one of these plots (A 4–1) was held in a condition of clean fallow for three years, from November, 1923, until April, 1927, at which time the scheduled crop was planted. Cotton plants began dying near the ends of the plot by the latter part of June, and by the end of the season (October 18) 36.8 per cent of the stand had been killed by root rot. In the early part of July two plants that were dead from cotton root rot were found near the center of this plot. This spot of infection spread until at the end of the season an

area approximately 10 feet in diameter was involved, but it remained isolated from the borders of the plot and from other diseased areas on the plot. Because of the findings made earlier in the season, as cited above, it was considered desirable, for the purpose of confirmation, to excavate this isolated area and determine whether deep roots of native trees were possibly responsible for maintaining the infection.

An area about 10 feet in diameter, centering around the first two plants that died, was excavated to a depth of 14 inches without finding any old roots. In a smaller excavation the taproot of one of these first two plants, which carried an abundance of mycelium, was followed to a depth of 36 inches. At a depth of 32 inches from the surface and about 3 inches from the taproot an old, thoroughly rotted piece of tree root was encountered. This old root was so thoroughly rotted that any attempt to pick up small pieces caused it to fall apart. A relatively thick mat of root-rot fungus strands was found on a small rootlet from the cotton taproot that was growing through this dead tree root. In tracing out the dead tree root, a larger root, about seven-eighths of an inch in diameter, was found running parallel with the row of cotton and about 8 inches south of it at a depth varying from 20 to 28 inches below the surface. Cotton rootlets were found along and through this old root at intervals and in every case carried the characteristic mycelium on their surfaces. Later examination of mycelium taken from the small cotton roots, from pieces of bark of the dead tree root, and from soil adjacent to the tree root disclosed the characteristic strands and the right-angled branching of acicular cells. Since the portion of the station on which this plot is located has been under very intensive cultivation since 1906, it is certain that the tree roots have had no supporting, aboveground growth for more than 20 years.

OBSERVATIONS AT SACATON, ARIZ.

C. J. King,[5] in unpublished notes, reports as follows:

In Arizona many observations have been made which show that the thick strands that extend to the surface of the ground as a part of the structure for the building up of conidial mats are very frequently connected with fragments of dead roots or masses of dead organic matter buried beneath the soil. (Figs. 3 and 4.) In the summer of 1927 further evidence was obtained which indicates that the organism may possibly exist on dead roots and become transferred to the roots of living crop plants when these are planted in close proximity. In 1926 a field near Goodyear, Ariz., was cleared of native plants and planted to alfalfa in the fall. In the summer of 1927 several circular spots of root-rot infection appeared in this field, and examination showed that conidial mats were abundant on the circumference of these spots. In making excavations within these spots many pieces of old roots and stems from the native plants were found, and some of these were covered with root-rot mycelium. In almost the exact center of some of these dead circles of alfalfa plants badly decayed stumps of *Lycium* spp. were found, on which Ozonium strands could be found in abundance. Upon digging up some healthy-appearing Lycium plants on the outside of the alfalfa field, where it was under its natural environment, the roots of these, too, showed the characteristic strands of the fungus coursing over the surface, but there appeared to be no injury to the plants aboveground.

Probably the most substantial evidence that the fungus can exist in nature as a saprophyte is the successful culture of it on various kinds of dead roots. At Sacaton, Ariz., it has been grown successfully on sterilized cotton roots that were dug up after being buried in the soil for one year (fig. 5) and two years. It was also grown on dead Lycium roots that had reached the state of being soft and

[5] Associate Agronomist and Superintendent, U. S. Field Station, Sacaton, Ariz.

disintegrated. On these materials the mycelium not only grew rapidly and in profusion, but sufficient food material was obtained from them for the development of large sclerotia.

OBSERVATIONS AT GREENVILLE, TEX.

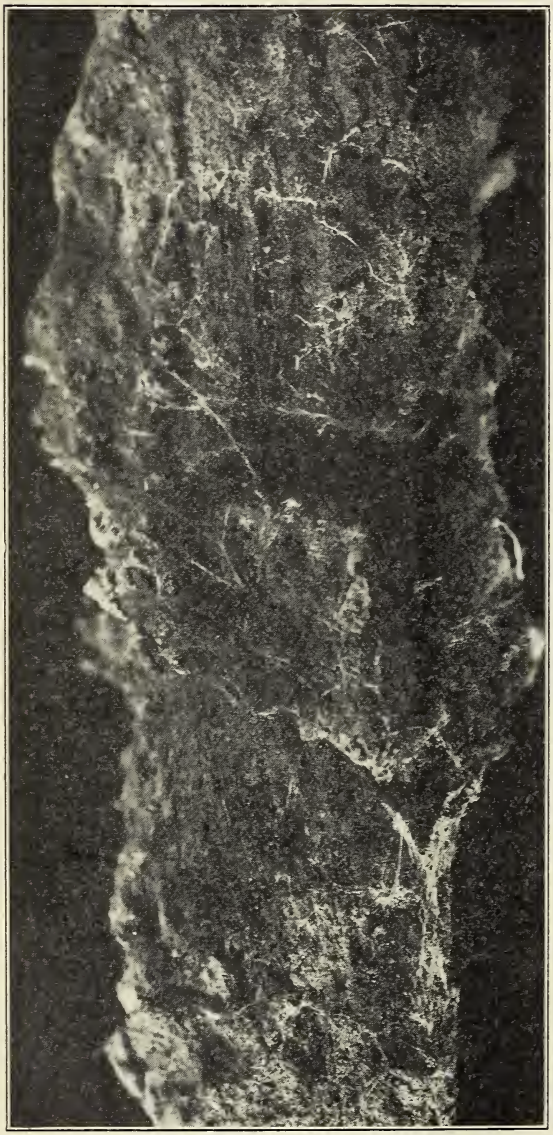

FIGURE 3.—Section of cotton stalk covered with active root-rot mycelium after it had been in the ground for two years, × 5. (Photographed by H. F. Loomis)

An interesting observation was made by Homer C. McNamara[6] on a series of three ¼-acre plots included in a test of one, two, and three year clean fallows as a means of controlling cotton root rot at Greenville, Tex. The following is taken from his notes:

The three plots had been in cotton continuously from 1921 to 1924, and the fallow treatments were begun in 1925. The first plot in clean fallow was returned to cotton in 1926 and showed considerable root rot. The second plot, adjoining the first plot and contiguous to the infection of 1926, was replanted to cotton in 1927. There was considerable advance of the disease from the first plot into the second, which, according to the behavior of the disease at Greenville, was anticipated. Throughout the summer the only plants to die in the plot that had been in clean fallow two years were on the west side, where the infection was carried over from 1926. It appeared that there would be no return of the disease on the side of the plot next to plot 3, which was in clean fallow for the third year.

Very late in the season a small spot extending across two rows appeared on the second plot, contiguous to the third plot, which was in clean fallow for the third successive year. This unexpected behavior led to an inquiry into the history of the plot. A map made in

[6] Assistant Agronomist and Superintendent, U. S. Cotton-Breeding Field Station, Greenville, Tex.

1919 showed that there had been a large mulberry tree located on the third plot near the point where the root-rot infection appeared.

An excavation of the spot was begun early in December, but heavy rains prevented further progress until the second week in January, when the digging was resumed. Old cotton roots were found in abundance under the dead plants to

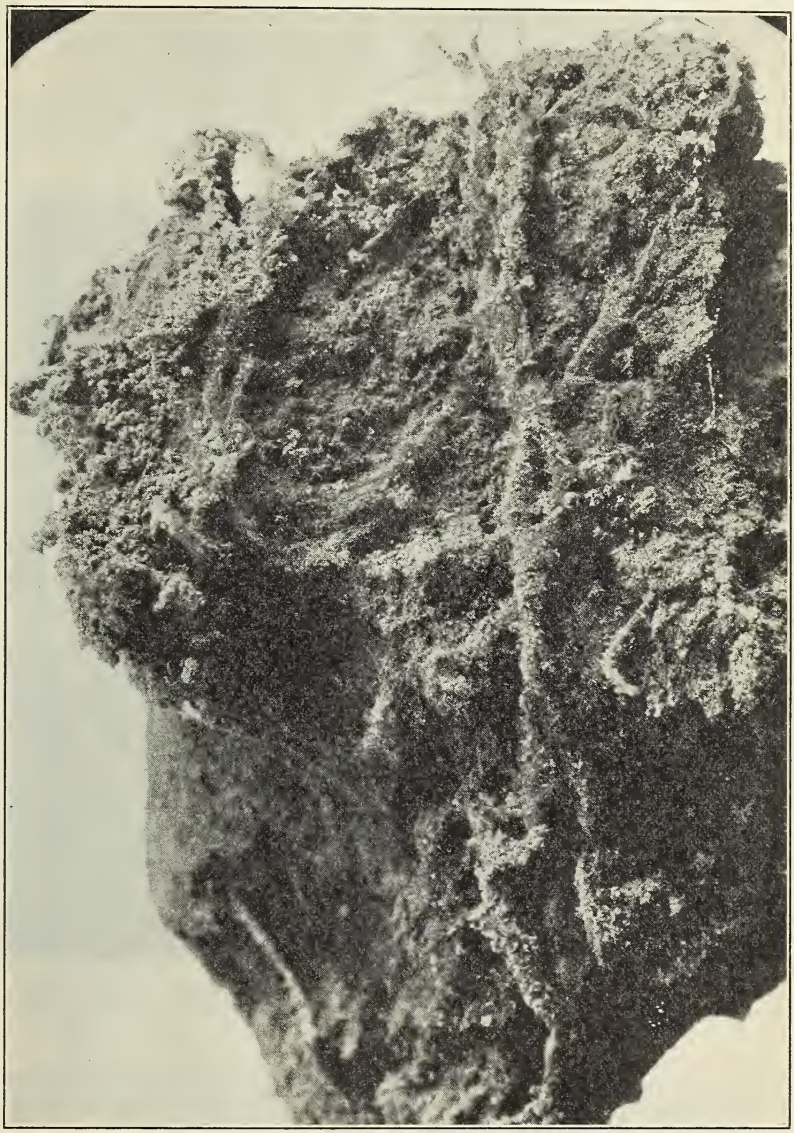

FIGURE 4.—Thick strands of *Phymatotrichum omnivorum* extending from buried fragments of dead cotton roots to the surface of the soil, where a conidial mat was formed. (Photographed by H. F. Loomis)

a depth of more than 4 feet. Numerous small roots, so badly decomposed that their identity could not definitely be determined, were also found. At a depth of about 26 inches a mulberry root was found in an advanced state of decomposition, with live cotton roots penetrating it, and with live root-rot mycelium on the cotton roots. This dead mulberry root was dug out, and the old stump

was found to be located in the fallow plot at a distance of about 11 feet from the dead cotton plants. After the old stump was found several other large roots were found leading off in the direction of the dead cotton plants.

Live mycelium was found on living cotton roots January 14; at a depth of 26 inches, where they penetrated the old mulberry root, but it was apparently not in evidence on the great mass of root material dug up.

The fact that root rot appeared on the east side of this plot in only one place, that this spot was only 11 feet distant from an old mulberry stump, and that the dead roots extended under the plants that died may be significant and have some bearing upon the saprophytic nature of the root-rot fungus.

Another interesting case was observed in the form of a small isolated spot appearing in a field where there had been no cotton for two years. In digging within the spot the old stumps of two cotton stalks were found near the center of the spot, supporting a good growth of active mycelium.

FIGURE 5.—Pure culture of root-rot mycelium growing on pieces of dead cotton roots of plants grown in 1926 sterilized and placed on prune agar in a Petri dish. Natural size. (Photographed by H. F. Loomis).

CONCLUSIONS

There has been some uncertainty as to how long the cotton root-rot fungus, *Phymatotrichum omnivorum*, could survive in the soil in the absence of living host plants.

The observations herein recorded show beyond a doubt that the causal organism of cotton root rot may be carried in an infectious condition in the soil over a period of several years on the roots of completely dead host plants, and they show why a system of clean fallow, even when rigidly maintained for as long as three years, does not insure a satisfactory reduction of root rot where deep-seated infections occur.

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